1.6 USE OF A MESONET DESIGNED TO IMPROVE UNDERSTANDING OF SURFACE WINDS IN LITTORAL REGIONS

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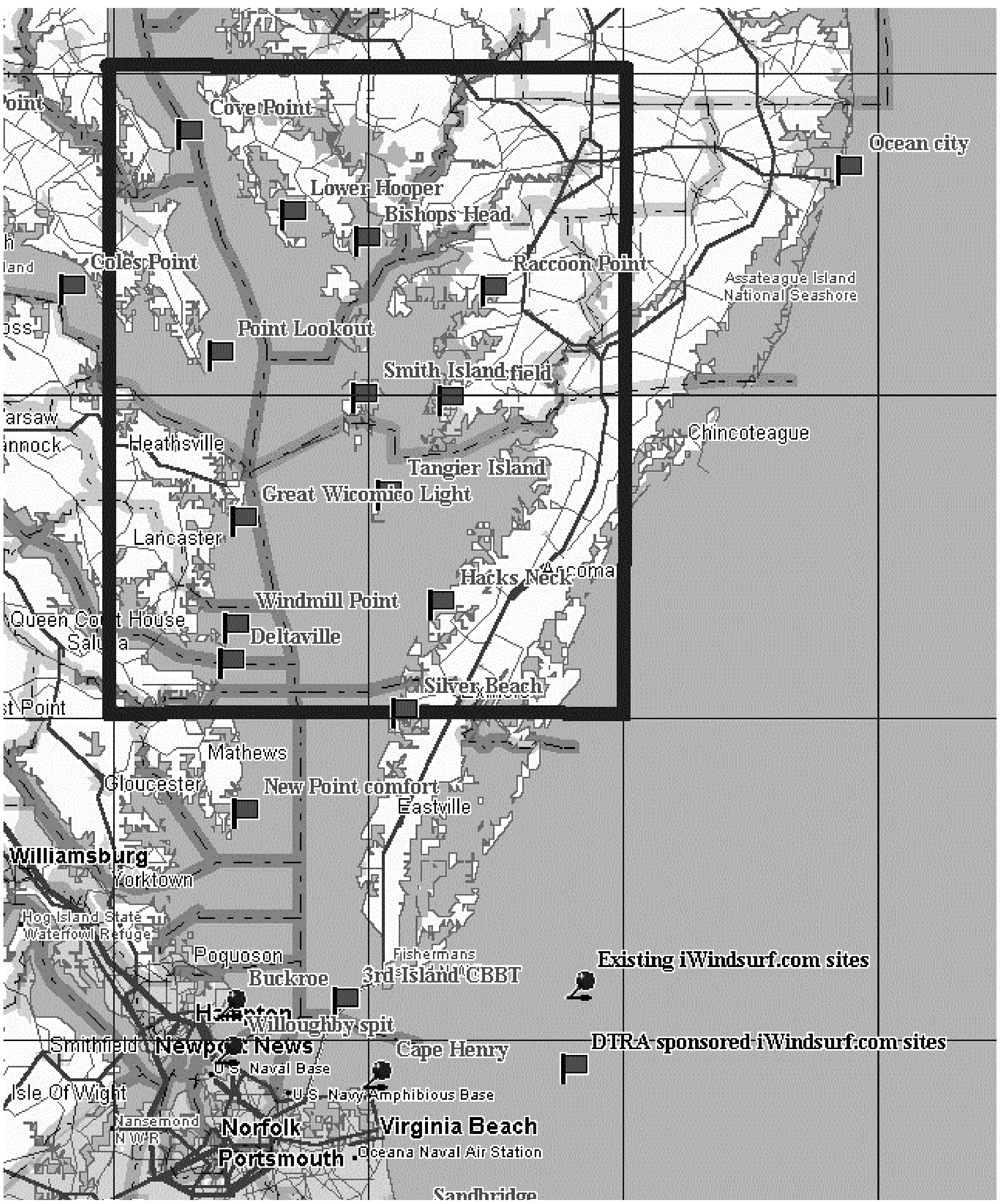
1. Introduction

The Sea Port of Debarkation (SPOD) Vulnerability and Ship Protection in the Littoral Region Weather Model Experiment was conducted this summer on the lower Chesapeake Bay. The primary goal of the experiment is to measure the improvement in the prediction of weakly forced mesoscale circulations in a littoral region based on an increased spatio-temporal resolution of surface characteristics. Higher resolution terrain and land use databases, in-situ measurements and remote sensing will obtain the improvement in surface characterization.
In situ measurements come from a variety of sources including a network of 17 automated weather stations installed and maintained by Marak Services, Inc. These stations yield a spatially thorough network when used in tandem with NOAA C-MAN, PORTS and NWS sites. The mesonet has utility on several fronts: First, the highly concentrated network of sites located at the land/sea interface is well-suited to capture sea-breeze circulations which often maximize at the interface. Second, the mesonet provides an independent source for model verification. Finally, information collected from the mesonet may improve model accuracy through assimilation into the input data stream.

2. MESONET

The 17-site mesonet was installed over the period* November 2000 to June of 2001. The sites were added to augment an existing network of sites operated and maintained by Marak Services. The sites are denoted by flags in figure 1.



The original mesonet was installed for use by the recreational boating community, and numbers over 150 sites nationwide (see www.iwindsuf.com). Prior to the new installation, five sites existed within or near the experiment domain (1 by 1 degree region, box on figure 1). Although primarily used for boating purposes, data from the mesonet has been used for research purposes as comparisons were made between observed winds and mesoscale model wind forecasts using the NOAA Air Resources RAMS model (Titlow and McQueen, 1999). For this study, the 15 new sites were added with the strategy in mind to capture mesoscale flows on the south central Chesapeake Bay. The new mesonet sites collect the following parameters: barometric pressure, air temperature, relative humidity, wind speed, wind direction, and water temperature (when accessible). The data are collected in 5-minute averages, and transmitted to a central transmission facility through standard phone lines. Radio telemetry is used to transmit data from Coast Guard navigational aids to a base station at three sites. All attempts were made to locate the instruments at the standard 10m heights, but in most cases, the desire to maximize fetch and maintain installation requirements dictated the need to alter elevations. The varied heights are typical in the marine environment due to limited locations in which are feasible to place instruments. Examples of instrument heights at National Ocean Data Center (NODC) nearby locations include Thomas Point Light at 18.0 meters, and Chesapeake Light at 43.3 meters. Table 1 lists the 17 sites along with location characteristics. Column "Distance to" gives an indication of the relative distance sensors deviate from the desired criteria of locating at the exact land/sea interface. If the instruments are located on the water (e.g., on pier or navigational aid), the value is distance to shore. If the sensor is located on land (e.g., on structure or pole), the value is the distance to water's edge.

	Site	*Lat decimal*	*Lon decimal*	*Sensor Height(m)*	*Sensor underlying surface*	*Distance to: (m)*
1	Cove Point MD	38.384	76.382	13	Land	W = 5
2	Point Lookout MD	38.04	76.322	15	Land	W = 3
3	Lower Hooper Island MD	38.258	76.179	10	Land	W = 2
4	Bishop's Head MD	38.217	76.033	18	Land	W = 5
5	Crisfield MD	37.97	75.87	12	Water	L = 800
6	Ocean City MD	38.328	75.086	15	Water	L= 20
7	Raccoon Point MD	38.141	75.785	9	Water	L = 8
8	Smith Island MD	37.974	76.041	10	Land	W = 10
9	Onancock VA	37.813	75.89	12	Land	W = 10
10	Silver Beach VA	37.485	75.962	14	Water	L = 650
11	3rd Island CBBT VA	37.036	76.077	15	Land	W = 5
12	Coles Point VA	38.142	76.614	9	Water	L = 160
13	Great Wicomico Light VA	37.783	76.277	12	Water	L = 1000
14	Tangier Island VA	37.823	75.991	17	Land	W = 5
15	Windmill Point VA	37.616	76.291	11	Land	W = 20
16	Deltaville VA	37.562	76.301	9	Water	L = 30
17	New Point Comfort VA	37.328	76.273	15	Land	W = 8

3. ANALYSIS

3.1 EXPERIMENT METEOROLOGICAL OVERVIEW

As stated in the introduction section, the theme for the field mission is to analyze weakly forced synoptic events. The time period late July is chosen because, climatologically, the lower Chesapeake region is typically under the auspices of Atlantic high pressure during this time period. Extensive ridge often builds over the entire eastern US for extended periods with the Chesapeake region governed by sunny, hot, and humid conditions. Ridges will often hold for several day stretches, and only briefly interrupted by weak cold front passages. Winds on the bay are primary generated by micro and mesoscale features during these periods. Much to the joy of the general populace, but sorrow of the experiment research group, this July was anything but normal. Discussion and statistics courtesy of National Weather Service Baltimore/Washington office on July 31st sums the situation up quite well: "WHAT A SUMMER ITS BEEN SO FAR. MAX TEMP AT DCA SUNDAY WAS 21 DEG BELOW NORMAL. ...TEMPS AT DCA FOR THE MONTH OF JULY ARE RUNNING 4.6 DEG BELOW NORMAL. SO FAR THIS SUMMER THERE HAVE ONLY BEEN 10 DAYS IN WHICH THE TEMP HAS REACHED 90F OR HIGHER AT DCA. NORMALLY...BY THE END OF JULY...THERE ARE 24 DAYS IN WHICH THE TEMP REACHES 90F OR HIGHER." The gist of the anomalous pattern is that the mainland United States has been in an omega-blocking pattern for about the last 2 months. With a long wave trough over the eastern US, the not-so-unexpected result has been an active synoptic pattern. The resulting sensible weather has included the following: multiple significant cold front passages, record low temperatures, cut-off lows, and a near non-tropical gale accompanied by over 4 inches of rain across portions of the domain. The region experienced some heat, but most was associated with an active southwesterly gradient as some mesonet sites maintained 20 knot plus winds during the extended hot periods. As a result, "weakly forced" synoptic events were not overly abundant during the 2-week mission. Despite the lack of expected locally driven flows, many small-scale features exposed themselves during the 2 weeks. A brief mention of some of the more significant events is covered in order to exemplify the utility of the coastal mesonet in revealing anomalous flow patterns.

3.2 EVENTS

3.2.1 ACCELERATED NOCTURNAL FLOW

One of the typical mesoscale flows seen during periods of weakly-forced synoptics, is an accelerated southwesterly flow that occurs during the overnight hours in the vicinity of Point Lookout. Limited sensors in the region have left the spatial extent of the increased flow as somewhat of an unknown. Figure 2 A and B are surface plots for 6 am local time on successive mornings of July 17th and 18th. Both depict the region of accelerated flow in the Point Lookout area.

Figure 2A

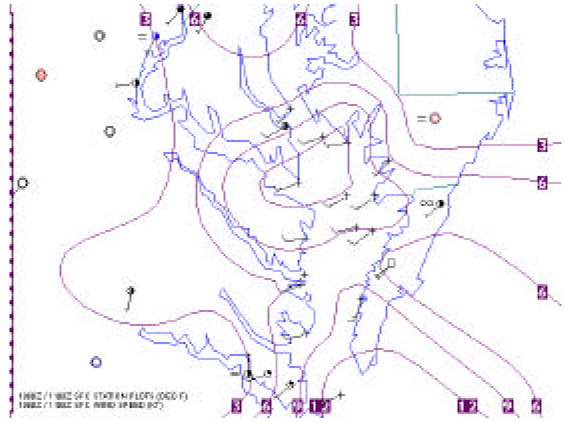


Figure 2B

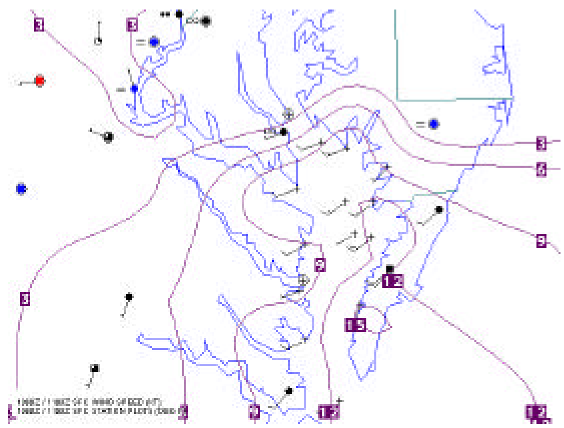


Figure 3 A through D contain graphs for Point Lookout (A, C), located on the open bay at the mouth of the Potomac River and Raccoon Point (B,D), west-facing but within the Manokin River on the eastern shore. It appears from the graph that area of accelerated nocturnal flow prevails on the open bay but does not penetrate many of the tributaries. From the graphs, one can see that peaks is diurnal curves in wind speed between the two locations are out of phase. That is, the strongest winds at Raccoon Point occur during the afternoon, while Point Lookout's peak occurs roughly between 1 to 7 am.

Figure 3A Pt. Lookout, July 17th

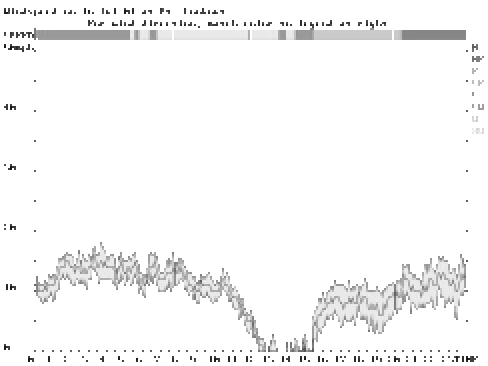


Figure 3B Raccoon Pt, July 17th

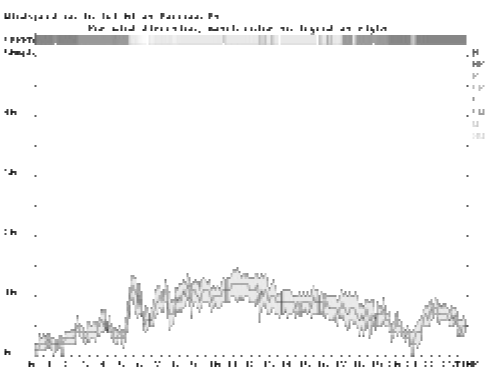


Figure 3C Point Lookout, July 18th

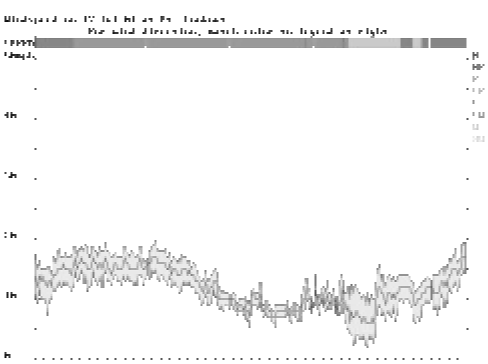
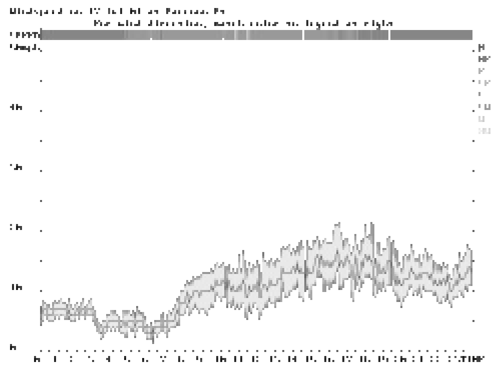


Figure 3D Raccoon Pt., July 18th



3.2.2 ONSHORE FLOW

A second and intuitively obvious flow during weakly-forced synoptics is localized onshore flow throughout the region. Although there were few occurrences of high pressure positioned immediately over the region, ambient flow did become weak enough for onshore flow to occur on several occasions. July 21st, 22nd, 23rd and the 28th all displayed onshore southwesterly flow in the northeast quadrant of the domain under light northeasterly synoptic gradient. In fact, the Figure 4 A and B display an excellent example on onshore flow on the afternoon of the 22nd when Raccoon Pt (B) on the eastern shore, and Coles Point (A) on the western shore go through 4 consecutive hours of 10 knot flow at 180 difference in wind directions.

Figure 4A Coles Point

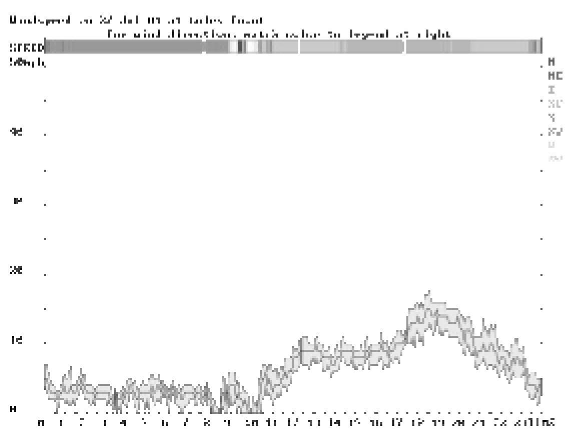


Figure 4B Raccoon Point

Possibly one of the more interesting and complex onshore flows blossomed on the lower eastern shore. Onshore Atlantic and onshore Chesapeake Bay flows collided when breezes fully matured and tried crossing the peninsula with the stronger ocean breeze. Mesonet sites' Hacks Neck and Silver Beach experience prevailing morning NE flow (see figure 5A) that backs onshore NNW to NW during the afternoon (see figure 5B). By 4pm (see figure 5C), the flow is then wiped out by a late increase from the E, SE. Possible explanation lies in an onshore ocean sea breeze that crosses the peninsula and arriving along western shores about 3 pm. Further to the north, morning NE flow flips onshore SW and W onshore flow at Crisfield and Raccoon Point. Then, both are also replaced by a backed SE flow that occurs a few hours later than the sites to the south (see figure 5D). Peninsula becomes much wider around Crisfield, thus the later onset time of the wind shift. Fetch is good to the SE, so once the ocean sea breeze remnants arrive, speeds rise quickly. Conversely, Raccoon Pt. is sheltered, so the backing event is much more dampened. The remnants of the ocean sea breeze appear to continue westward out into the bay. Tangier sees an abrupt upward bump between 5 and 6 pm, with a dampened bump at Smith Island too around 6:30 pm (also figure 5D map). In fact, Great Wicomico Light and Pt. Lookout even indicate a possible ocean-induced upward bump in SE flow around 8 pm.

Figure 5A 1400 UTC

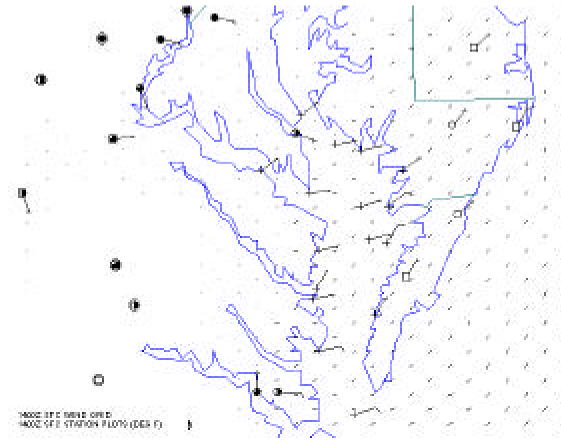


Figure 5B 1900UTC

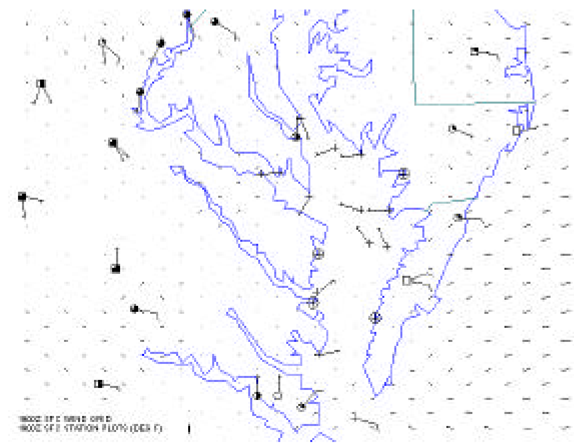


Figure 5C 2000 UTC

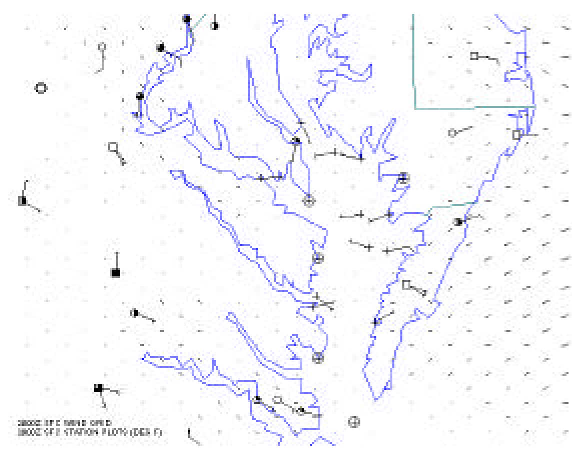
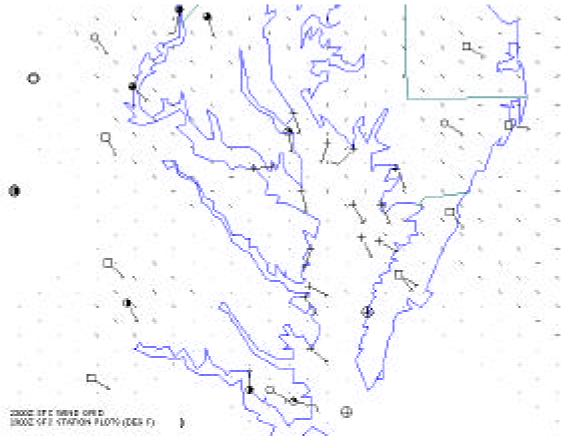


Figure 5D 2300 UTC



3.2.2 BAY AND RIVER CHANNELING

Channeling of flow along bay and river near-shore waters is another of the expected anomalous flows that is often a frequent occurrence during weakly-forced synoptic patterns. As bay and river breezes develop during the mid-day and afternoon hours, the general slow strengthening and veering pattern of winds from east to southeast to near due south by late day will temporarily bring a period of side-onshore flow, say 30 degree off of parallel to the local shoreline. During this time the hard shore line, combined with the temperature difference between warmer land and cooler water bring a period of accelerated flow. Along the western side of the bay, conventional wisdom would predict that the southern shores of east-west oriented rivers (e.g., Rappahannock) would see a slight accelerated flow first, followed by southern shores on northwest-southeast oriented rivers (e.g. Potomac), with a slightly stronger period of increased flow, and finally on the bay itself (oriented north-south) with the latest, and often strongest peak flow. During the experiment time frame, there was a general absence numerous channeling events, but none-the-less, southeast and southerly pulses did occur on several occasions. The 22nd and 28th both displayed this pattern.

3.2.3 MARINE-INDUCED VARIATIONS IN SYNOPTIC FLOW

Although not the focus of this experiment, the mesonet also revealed some interesting variations in synoptic flow within the coastal environment.

For example, on several occasions pre-frontal southwest flow will be interrupted by mid0day lulls on portions of the bay. The Point Lookout and Chesapeake Bay Bridge tunnel regions are quite popular for mid afternoon periods of remarkably light southwesterly flow when surrounding location exhibits consistent moderate southwesterly flow. The 24th is an excellent example of such an event. Figure 6 depicts the daily wind speed chart or Point Lookout. A pronounced dip is evident around 14 UTC local time. Mesoscale model output for the same time is displayed in figures 7 and 8. Figure 7 is the NOAA Air Resources Lab version of RAMS run at 4 km resolution, while figure 8 depicts forecast flow using the ARPS model with 15 km resolution. Although difficult to discern from the figures, neither displays the light speeds measured by the sensor. The 4 km RAMS model does indicate a local minimum on the eastern shore of the bay across from Point Lookout (dark region), while the ARPS indicates a minimum too but even further displaced over southwest Delaware.

Figure 6

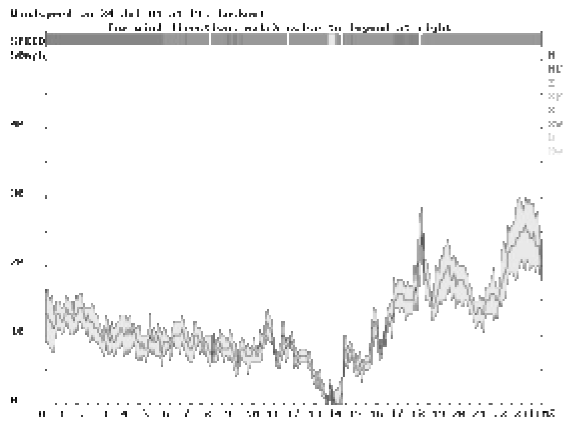


Figure 7

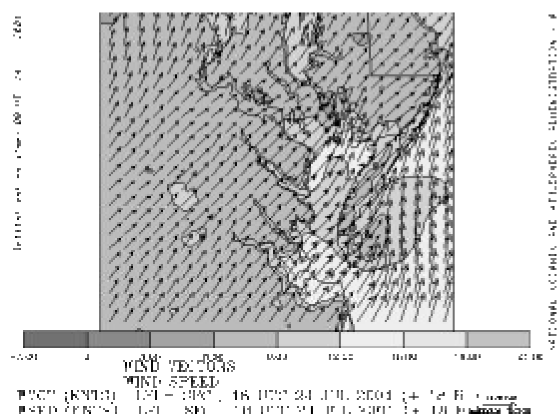
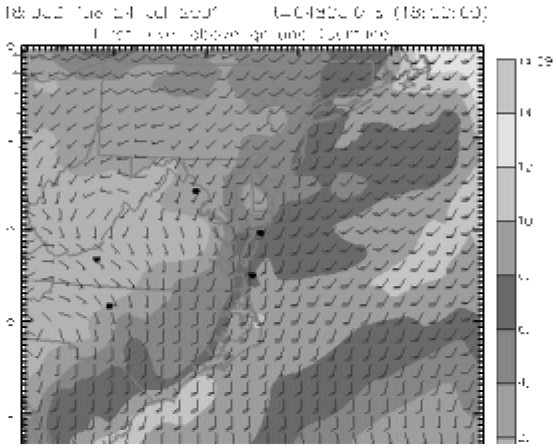


Figure 8



4. CONCLUSIONS

Despite the less-than-desirable ambient weather conditions during the experiment, the mesonet clearly revealed a variety of wind patterns during weakly forced events and marine-influenced synoptic flow variation. In the absence of these sites, significantly varying flows would remain unresolved. It appears that mesoscale models, although becoming much more realistic in parameterizations, still can struggle in coastal regions even situations governed by fully developed synoptics. In depth analysis is currently taking place to determine the level of model performance in weakly forced events, and whether including mesonet data itself in the model input stream can raise the level of forecast accuracy.

5. REFERENCES

Titlow, J.K. and J.T. McQueen, 1999: On the Use of a Coastal Mesonet as a Tool for Mesoscale Model Evaluation. Third Conference on Coastal Atmospheric Prediction and Processes, New Orleans, LA, American Meteorological Society.

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